MODELING OF POWER AND PROPULSION PARAMETERS FOR NUCLEAR ELECTRIC PROPULSION MISSION STUDIES*

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ABSTRACT

Advanced propulsion mission studies sponsored by NASA over the past 10-15 years have indicated that Nuclear Electric Propulsion (NEP) may be a viable candidate for a detailed exploration of the solar system.[1,2,3] The first generation of NEP to be used for planetary missions will most likely be based on modest technology improvements to already existing designs or hardware for a technology readiness in the 2000-2010 time frame. As such NEP will depend upon the development of small space nuclear reactors such as SP-100 and enhancements to ion thruster technology to provide the high power and specific impulse required of NEP systems. The very first NEP planetary missions, however, may be performed using only conservative thruster performance and modest reactor power levels of 20-50 kW. These first planetary NEP missions would also likely employ an expendable launch vehicle with a chemical injection stage to insert the NEP spacecraft into an escape trajectory from the Earth before the nuclear reactor and thrust system are turned on.[3]

In order to evaluate the potential benefits of an NEP system and to provide a reasonable design goal for an NEP development effort, a selected set of scientifically interesting planetary missions must be examined. A detailed parametric analysis of each of these missions, although desirable, may not be feasible because of the number of free parameters, such as flight time, launch energy, reactor power level, thruster specific impulse, associated with each mission. As a consequence, in NEP planetary mission studies the free parameters are optimized and the performance examined with flight time used as an independent variable. In order for an accurate assessment of performance, ie. payload, to be made it is thus important to model both the power and propulsion system as accurately as possible based on predicted technology for the period of interest.

Technologists frequently use power or propulsion system specific mass as an indicator of the

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performance of these systems. This specific mass is primarily an indicator of the maturity of the particular hardware but is not generally useful to the trajectory analyst. This specific mass is traditionally defined as the total system mass divided by power level. This definition of specific mass dots not, however, define how the pal-titular system mass varies with power level and it is this latter quantity that must be used in optimization studies. Thus what is required for a valid optimization of system parameters in trajectory and mission studies is the variation of the system masses with power level, Also important in this optimization analysis is as accurate a description as possible of the individual thruster operation, ie: the variation of thruster power level, lifetime and mass with specific impulse of the thruster. Expected thruster lifetime is important since the total required propulsion time for many proposed missions may greatly cxc.cccl the expected lifetime of a single thruster and multiple sets of thrusters would need to be included. The total propulsion system mass may also be a strong function of specific impulse since an individual thruster operates at a power level that J-nay monotonically increase With specific impulse. As a consequence the number of operating thrusters must increase for a given total input power level as the specific impulse decreases. These factors must all be considered in order to adequately assess the performance of these NEP systems for planetary missions.

in this paper the modeling of both the nuclear reactor power system and thrust or propulsion system is considered for the trajectory code used for the present NEP mission studies, The modeling of these systems is formulated such that changes in reactor and thruster technology arc easily accommodated, The paper includes both the equations which enable the various system parameters to be optimized and equations enabling launch energy to be optimized for selected launch vehicles. Finally examples of optimized NEP trajectories are included for several selected planetary missions,

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